TABLE 2.—*Average of the yearly growth, etc.*—Continued.

Year.	Average growth. X Group of 25.	Y Group of 7.	Z Group of 2.	Year.	Average growth. X Group of 25.	Y Group of 7.	Z Group of 2.
	Mm.	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*
1445			1.40	1429			1.60
1444			1.40	1428			1.55
1443			0.95	1427			1.40
1442			2.10	1426			2.45
1441			1.20	1425			2.80
				1424			1.80
1440			1.80	1423			2.55
1439			1.55	1422			3.00
1438			1.25	1421			2.40
1437			1.70				
1436			1.70	1420			2.05
1435			1.75	1419			2.00
1434			1.20	1418			1.90
1433			1.55	1417			2.60
1432			1.30	1416			2.00
1431			1.50	1415			3.25
				1414			1.85
1430			2.15	1413			1.90

SQUALLS AND THUNDERSTORMS.

By J. LOISEL, D. ès S. Dated, Observatory of Juvisy.
[Translated from La Nature, 1909, 37:105-8, by C. ABBE, jr.]

Half a century ago thunderstorms were believed to be essentially local phenomena not subject to any [general] law. It was not until it had been shown that the majority of these storms travelled in a definite direction that a distinction was made between thunderstorms accompanying barometric lows and local or heat thunderstorms. I shall here confine myself to the consideration of the former class only. This class has been the object of researches by a large number of meteorologists: Marié-Davy, Mohn and Hildebrandsson, Abercromby, Ley, Köppen, Ferrari, von Bezold, Prohaska, and others. Each has untangled a portion of the truth, but to the French meteorologist, E. Durand-Gréville,[1] belongs unquestionably the credit for having sharpened the previously somewhat vague and indistinctly connected ideas, and for having adequately correlated the authentically verified facts bearing on this subject. He showed that the "cyclonic" thunderstorms are but an accessory result of a body of extremely complex phenomena—an organism one may call it—*the squall* (*le grain*), which is subject to fixed laws and forms an integral part of certain lows. He further showed that these constitute a regular incident, subject to definite laws, in the general circulation of the atmosphere.

The thunderstorm is a *thundersquall* (*un grain orageux*).

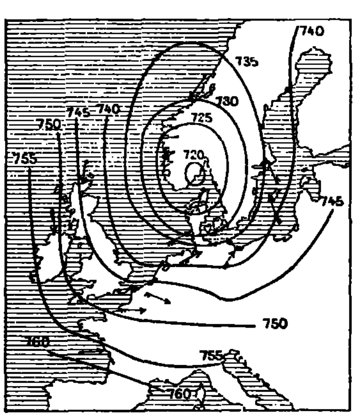

FIG. 1.—Pressure chart of western Europe, morning of March 12, 1906.

[1] E. Durand-Gréville: Les grains et les orages. Bur. cent. mét. de France, 1892; and Comptes rendus, 9 avril, 1894.

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Fig. 1 exhibits the barometric conditions prevailing over western Europe on the morning of March 12, 1906, with a barometric depression or low of regular outline central just south of Christiania. In certain lows, however, the isobars instead of curving so regularly present a zigzag at one or more points and Durand-Gréville has called this the "squall zigzag" (*zigzag de grain*). Figure 3 shows in a diagrammatic but accurate manner the details of this distortion of the isobars. The narrow band included between the dotted lines constitutes the "squall zone" (*le ruban de grain*). It starts in the vicinity of the center of the barometric depression or low and usually extends out to its boundary, thus having a length of 2,000 kilometers (1,243 miles), or even more at times, while its width varies from 10 to 80 or 100 kilometers (6 to 62 miles). The "squall zone," while remaining parallel to itself, moves across the country with its "low." If the depression moves eastward the "zone" follows it, perhaps gradually accentuating its convexity eastward as shown in the two maps of fig. 2. If the low retreats westward the zone retrogrades with it, as shown in fig. 4. If the low remains stationary, however, the "squall zone" does not necessarily follow suit; in the majority of cases it swings around the center of the depression.

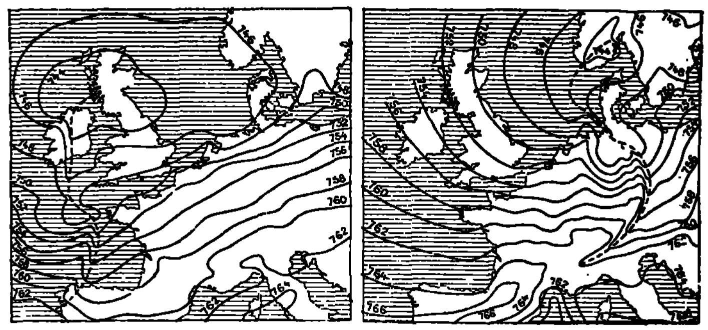

FIG. 2.—The eastward displacement of a "squall zone" (*le ruban de grain*).

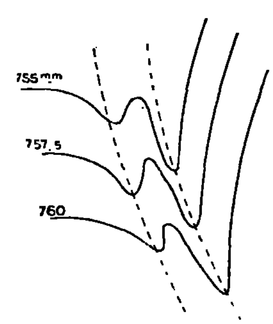

FIG. 3.—Course of the isobars within the "squall zone."

A general review of all the observed facts shows that the passage of a "squall zone" past each place is accompanied by the concomitant production of a certain number of phenomena which occur only within the limits of the zone. They begin at the moment when the "squall front" (*ligne de grain*) of the "squall zone" reaches the place of observation, they rapidly attain their maximum intensity, and then gradually weaken and die out as the rear of the zone passes and normal conditions become reestablished. But these accompanying phenomena may be more or less numerous, whence result many varieties of "squalls," each characterized by its appropriate phenomena.

We shall see that the phenomena observed during the passage of a squall are actually the results of two causes, one of these, the squall wind, is purely *dynamic*, pre-existant, and may be of distant origin, the other is the local condition of the atmosphere and is *static*.

The following synoptic table by Durand-Gréville summarizes the principal varieties of "squalls."

Durand-Gréville's classification of squalls.

1. Sudden increase in wind velocity				
2. Sudden change in wind direction	White squall.			
3. Sudden rise in pressure				
4. Sudden fall in pressure		Wind squall.		
5. Sudden rise in relative humidity				
6. Rapid increase in cloudiness			Rain, hail, or snow squall.	
7. Downpours of rain, hail, snow				Thunder squall.
8. Lightning and thunder				

In the above table squalls are classified in the order of increasing complexity. On the other hand, their geographic distribution would give a quite different arrangement.

FIG. 4.—Westward displacement of a "squall zone."

Figure 7 shows graphically the changes in four of the meteorological elements observed during a squall on July 28, 1908, at the observatory of Juvisy, and brings out very clearly the general characteristic changes in each, so that further description is not necessary.

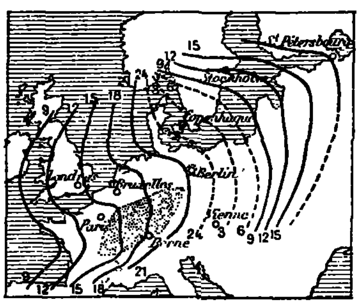

FIG. 5.—Successive positions of the "squall front" (*la ligne de grain*) of August 27–28, 1908, and the districts visited by the thunderstorm.

A glance at the wind curve in fig. 7 shows that the "squall zone" is the seat of a strong, sometimes even violent, wind generally from points between north and west, while in front and behind this zone the wind is much weaker and blows from points between south and west. In front and behind the "squall zone" the wind direction makes a slight angle with the isobars by reason of the deflective force of the earth's rotation. At the moment of the squall the wind direction is almost at right angles to the isobars, since the influence of the deflecting force is less marked on a brisk stroke of wind blowing along a narrow path only. It is evident that this violent "squall wind" is not fed by the much weaker wind blowing behind it. In all probability, and some observations unfortunately all too few apparently confirm the hypothesis, it can be "nourished" only by a sheet of rapidly *descending* air which comes from the higher regions (see A, fig. 6), and after brushing the ground over the more or less extensive space RR' as the "squall wind" (*le vent de grain*), must then necessarily ascend toward A', leaving the "squall front" (*ligne de grain*), since it cannot escape along the surface in advance of the "squall zone" where, as we shall see later, the wind is weak or even opposite in direction as though drawn in by the "squall front."

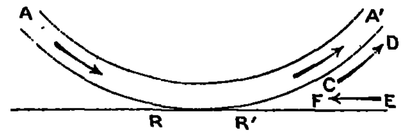

FIG. 6.—The arrangement of the winds in a squall (vertical section).

From what altitude does this sheet of air descend? To what height does it remount? We have no positive knowledge on this matter at present. All that one may assert is that certain squalls cross lofty mountain ranges without apparent disarrangement, while other squalls seem to produce much weaker atmospheric changes at the altitude of the Eiffel Tower than on the ground at the Bureau Central Météorologique. It is a complicated problem. Some meteorologists believe that we have in the squall a kind of atmospheric wave or breaker or vortex rotating about a horizontal axis. The writer believes that there is much of the hypothetical in this conception. Only the attentive observation of the upper clouds in those squalls which have *very little* accompanying cloudiness will enable us to decide as to the actual existence of an upper portion closing this circuit. One thing is very certain, a squall is in no way to be likened to a vortex having a vertical axis, i. e., to a minute barometric depression, as was long believed to be the case. As a matter of fact the "squall wind" does not blow spirally like a whirlwind, but on the contrary it blows always in the same direction, almost at right angles to the "squall front," and there is nowhere such a central calm as there is in a vortical or whirlwind movement.

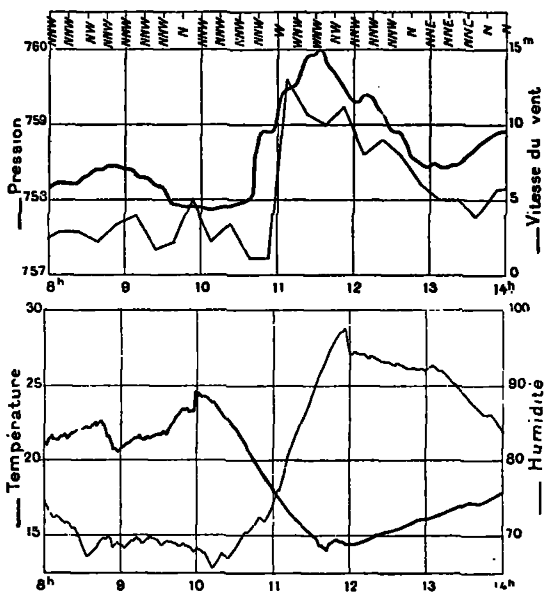

FIG. 7.—Changes in the meteorological elements at any locality, caused by the passage of a squall.

It is easy to deduce the consequences of such a state of affairs. The ascensional movement of the sheet of air $A\ A'$, fig. 6, sets up a kind of draft, $C\ D$, on the contiguous air layers, and this simultaneously produces in front of the squall the following phenomena:

1. A decrease in the velocity of the wind which may, as observations show, die out completely or be replaced by a weak contrary wind blowing in the direction *EF* toward the "squall zone" at right angles to its front.

   The whirls of wind and dust which sometimes immediately precede thunderstorms are probably provoked by the meeting of these two opposing currents, *EF* and *CD*.

2. A fall in pressure all along the front of the squall throughout a more or less narrow region which Durand-Gréville calls the "squall trough" (*le couloir de grain*), and which is revealed in the local barograms by the minimum preceding the sudden rise in the curve (see fig. 7, pressure curve at 10^h.).

As for the rapid rise in pressure which is particularly marked a short distance within the front boundary of the "squall zone," its primary cause is evidently the vertical component of the descending wind probably aided by various secondary processes such as the partial local evaporation of rain,[2] or still more the mechanical transportation of air by the rain drops.[3] This characteristic irregularity or "hook" (*crochet*) in the barograph curve was first noticed in the case of thunderstorms, whence it received the name "thunderstorm hook" (*crochet d'orage*) [or "thunderstorm nose" (*Gewitternase*)]. As a matter of fact it always occurs upon the passage of a squall, even when there is no thunderstorm. The above names are therefore incorrect, they should be changed to "squall hook" (*crochet de grain*) [or "squall nose"].

The low temperature within a squall can scarcely be explained in any other way than by supposing that the original temperature of the masses of descending air was lower than that appropriate to their altitude, wherefor they show less heating in the course of their descent.

Similarly the cause of the rise in the relative humidity is very probably to be sought in the action of the descending cold air upon layers of air near the earth's surface which are always more or less heavily charged with moisture.

LOCAL PHENOMENA.

All the phenomena so far considered exist throughout the extent of the "squall zone"; they are not special or localized at the point of observation. We have now to consider, on the other hand, local phenomena distributed chiefly close to and a little behind the "squall front" and which may develop simultaneously at various points in the "squall zone," leaving great gaps between. These are called forth by the passage of the cold descending[4] air of the squall through an atmosphere properly prepared, which thus becomes the occasional cause of local phenomena.

It is indeed easy to understand that collections of clouds of all sizes will form wherever the cold descending "squall wind" meets the warm, moist lower air; that sudden downpours of rain, snow, or hail, will be produced in those less numerous regions already enclosing large completely formed cumulo-nimbus[5] clouds; and that the thunderstorm will burst particularly at the hottest time of the day in yet more circumscribed regions of great heat and high humidity and filled with lofty cumulo-nimbus surmounted by "mushroom" or other forms of false cirrus. For example, the regions visited by the thunderstorm of August 27–28, 1890, are shown by the stippled areas of fig. 5. They were three in number, the first in the south of France, the second in the district about Berlin, the third and much the largest area embraced central and eastern France, the grand duchy of Baden, Würtemberg, and the major portions of Switzerland and Bavaria. The "squall front" traversed these thunderstorm regions on August 27 between 13^h and 22^h local time.

Upon examining the successive positions of the "squall front" as shown in fig. 8, we see that during an interval of several hours, the isochrones of the passage of the squall did not notably change their shapes, and that the speed of translation of the "squall front" was almost constant. It is evident that it would be extremely easy, as was originally suggested by Durand-Gréville, to report to a central station the passage of a "squall zone" by means of one or several lines of signals or stations located in the west of Europe. One could thus determine the position of the "zone," its speed of translation; in a word watch it, follow it step by step and consequently, several hours in advance, warn regions lying in its path of the probability of the occurrence of a squall at about a given hour. One could then notice at each point whether the passage of the squall would call forth from the local atmospheric conditions, a simple shower, a gust of hail, or even a thunderstorm at those localities where in popular parlance it was "thunderstorm weather."

From this standpoint it seems to me that the use of some one of the electric-wave-detectors [the coherer of wireless telegraphy] recommended by A. Turpain[6] is the proper method to adopt for the local prediction of thunderstorms. The method of general prediction based on the observation (and charting) of the "squall zone" might thus be very happily supplemented in particular cases.

For the sake of completeness I would add that one and the same barometric low may be accompanied by several "squall zones" disposed radially about it and succeeding each other at intervals of some hours. Further there are complex "squall zones" or zones made up of several parallel neighboring "bands," each "band" (*bande*) when considered alone possessing the characters of a simple "zone."

Theoretically, there is nothing simpler than to predict the arrival of a "squall zone." But it is a long step from theory to practise. One has but to recall how much energy, perseverance, and even obstinacy, Le Verrier needed through long years in order to overcome the material difficulties and the individual antagonisms or collective oppositions *"which are in the nature of things."*

EXHIBIT OF METEOROLOGICAL DATA.

By D. T. MARING, Instrument Division. Dated August 14, 1909.

A subject frequently of great perplexity to Weather Bureau officials is that of presenting meteorological data to the public in the most attractive manner. From the earliest days of the service maps and charts have been found, and still are, indispensable for illustrating graphically various sorts of atmospheric conditions and results, and it is hardly practicable to improve on these in any way, except as to higher grade of workmanship, finish, and color printing. But the introduction of the street shelter, or kiosk, opens up new possibilities and requirements in this direction; the exhibit of certain data to the public in the most simple and efficient manner being most desirable. The reading of graduated and figured scales is universally understood, and it is only necessary to take advantage of this fact in preparing such meteorological data as normal precipitation, temperature, etc.,—elements of interest to almost everybody. A plan for showing *rainfall* data, complete, by vertical scales is illustrated in the accompanying figure.

For this suggested scale we use simply any arbitrary system of graduated lines, of units and tenths, and number these in a series that will take in the range desired from zero (0) to and beyond the normal. A suitable adjustable pointer legend, *L*, at the top gives the average annual precipitation at the station from the commencement of observations, e. g., 43.50 inches, as

[2] E. Mascart: Journal de physique, 1879, p. 329–336.

[3] W. Köppen: Beiträge zur Kenntniss der Boen und Gewitterstürme. Ann. Hydrog. marit. Met., 1879, p. 324–335.

[4] I am of the opinion that the wind is not an ascending one outside and in front of the squall "zone" in those regions where no particular phenomenon has, as yet, been observed.—*J. Loisel.*

[5] M. Loisel here uses the term nimbus as it is used generally in Europe, and will be used during 1910 by United States Weather Bureau observers (see Instructions for preparing meteorological forms, 1910, par. 101-2).—*C. A., jr.*

[6] A. Turpain in La Nature, 1 mai, 1909.